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(54) Interface system for magnetic resonance imaging coils

(57) A magnetic resonance imaging system includes a patient couch (10) which selectively positions a patient relative to an examination region. An imaging coil (B) is disposed adjacent to a region of interest for receiving magnetic resonance signals emanating from the patient. A processor (48) both controls the imaging event and processes received signals from the imaging coil. A plug and socket assembly (24, 26) having a proximal component and a distal component relative to the imaging coil provides selective electrical connectivity between the imaging coil (B) and the processor (48). A non-volatile memory device (86), such as a 1-WIRE™ EEPROM, is affixed to the proximal component of the plug and socket assembly (24, 26) for storing a variety attributes associated with the imaging coil. The memory device is most conveniently mounted to a coaxial connector (110).

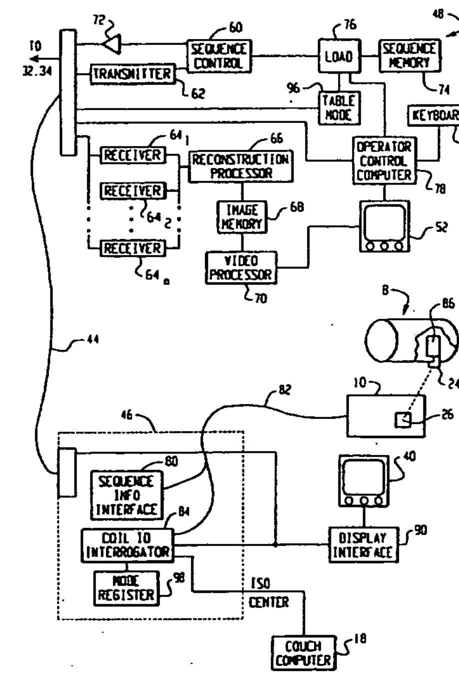


Fig. 2

EP 1 130 412 A2

Description

[0001] The present invention relates to radio frequency coils for magnetic resonance imaging systems, especially the radio frequency coil front end interface system for magnetic resonance scanners. The invention finds particular application in conjunction with an intelligent detection and recognition system for identifying and retrieving data associated with a radio frequency imaging coil. The invention will also find application in conjunction with spectroscopy, cable connection and interface systems for radio frequency coils and the like.

[0002] Horizontal or bore-type magnetic resonance imagers commonly include a bore dimensioned to receive a patient to be imaged. The bore is surrounded by a magnet assembly for generating a temporally constant magnetic field axially through the bore. Whole body radio frequency and gradient coils typically surround the bore. A patient couch supports and transports the patient into and out of the bore. More specifically, the patient couch is commonly height adjustable. The patient support surface is retractable from the bore for positioning the patient therein and extendable into the bore.

[0003] Analogously, in vertical field or open magnetic resonance imagers, pole pieces are typically positioned above and below the patient. Magnetic coils are associated with the poles to create a temporally constant field vertically between them. Gradient field and radio frequency coils are typically mounted to the pole structures.

[0004] When doing localized scans such as head or heart scans, a distinct localized coil is commonly positioned closely adjacent the patient. Cables, typically coaxial cables, are connected between the coil and a radio frequency receiver and/or transmitter.

[0005] One known technique to determine what type of coil is in a machine discloses a coil (specifically, a head coil) with an 8-pin connector. A selected one or a selected pattern of the pins are connected to ground to provide an 8-bit binary identification of the insertable coil. A digital circuit reads which pins are and are not shorted to ground as 1's and 0's and uses digital logic to indicate to the computer the type of coil installed.

[0006] One disadvantage of this system is that it is very complex to manage a multiple conductor cable because it is large and prone to pick up stray radio frequency signals. Moreover, if one of the wires or contacts fails, an incorrect indication of the type of the installed coil is provided to the computer. This erroneous indication of the installed coil could cause an imaging sequence to be initiated which could injure the patient or cause damage to the magnetic resonance equipment.

[0007] Another disadvantage of this type of a system is the limited amount of data located on the coil, specifically 8 bits. To determine all of the potentially needed attributes of a coil, for example, model number, number of operating modes including details for each, particular decoupling voltages and the like, resort is typically made to a look-up-table accessible to the processor. In other words, the data for the coil is not resident on the coil itself, making upgrades and changes difficult.

[0008] Another known technique to determine which one of a plurality of coils is in a MR machine uses a resistive element at a plug or interface between the RF coil and the processor. Accordingly, when the coil side plug is inserted into the MR system receptacle, the processor can determine the resistance, and then determine the inserted coil based on a known relationship between resistance and coil type. Undesirably, this technique can only distinguish a relatively small number of discrete coil types. Further, once the resistive value is determined the processor must still resort to a lookup table, typically resident on the system side of the MR machine, to ascertain operating modes and characteristics.

[0009] Yet another technique to distinguish between a variety of coils potentially usable in a machine involves a microprocessor system buried within the coil side of the system. The microprocessor based solution also suffers from several undesirable aspects such as: 1) An additional line required for providing power to the processor; 2) Additional support components, like voltage regulators, decoupling and/or filtering capacitors, etc., and a printed wiring board on which to mount them; 3) The inherently ferrous nature of the packaging materials of processors, which can lead to localized distortion of the main magnetic field; and 4) All the inherent problems associated with suppressing and/or eliminating the EMI noise generated by the local oscillator which provides the main "clock" for the processor.

[0010] In accordance with one embodiment of the present invention, a magnetic resonance imaging apparatus includes an imaging coil selectively connectable to a processor through a plug and socket assembly. The plug and socket assembly has a proximal component on the coil side of the assembly, and a distal component on the processor side of the assembly. A memory device is affixed to the proximal component of the plug and socket assembly for storing data attributes particular to the image coil.

[0011] One advantage of the present invention resides in the relatively large number of ID codes possible.

[0012] Another advantage of the present invention resides in the coil-side embedding or storage of coil attribute information for subsequent retrieval.

[0013] Yet another advantage resides in the ability to introduce new coils and/or new functionality without having to update MR-side software.

[0014] Ways of carrying out the invention will now be described in detail, by way of example, with reference to the accompanying drawings, in which:

FIGURE 1 is a diagrammatic illustration of a magnetic resonance imaging system in accordance with the present invention;

FIGURE 2 is a more detailed diagrammatic illustra-

tion including details of the front end interface and related hardware in accordance with the present invention;

FIGURE 3 is an exemplary illustration of a data arrangement within the memory device suitable to the present invention;

FIGURE 4 is an exemplary illustration of a coaxial connector and memory device within a plug;

FIGURE 5 is another view of the plug of Figure 4; and

FIGURE 6 is an illustration of an exemplary plug and socket assembly suitable for the present invention.

[0015] With reference to FIGURE 1, a patient couch assembly **A** selectively inserts and retracts a patient and a localized coil assembly **B** into and out of an examination region of a magnet unit **C**. The patient couch A includes a patient supporting surface **10** which is drivable by a drive motor **12** or manually movable into and out of a bore **14** of the magnet unit. The patient supporting portion **10** is slidably mounted on rails **16** which are connected with a scissor unit or other mechanical system for selectively raising and lowering the patient supporting surface **10**. When a non-permanent coil is needed, the patient supporting portion **10** is fully withdrawn from the bore or advanced fully through the bore to mount a selected one of a plurality of insertable localized coils thereon. Thereafter, the patient is positioned and the patient supporting surface is advanced into the bore.

[0016] Each localized coil **B** includes a dielectric former **20** on which a radio frequency coil **22** is supported. A plug **24** is connected with the localized coil for receipt in a socket **26** disposed in the patient supporting surface **10**. With certain coils, the plug **24** is affixed to one end of a coaxial cable bundle with the other end electrically connected to the coil.

[0017] The magnet unit C includes magnets **30** for generating a temporally constant magnetic field along a central or z-axis of the bore **12**. A whole body gradient coil assembly **32** and a whole body RF coil **34** are mounted around the bore **14**. A radio frequency shield separates the whole body gradient and RF coils. Of course, open or vertical field magnets are also contemplated.

[0018] An operator display panel **40** is mounted to the magnet assembly for providing a display to the operator concerning the position of the patient supporting portion **10**, the type of RF coil, the location of the RF coil, any errors or defects in the RF coil, and the like. An operator control panel **42** receives operator commands which are communicated to the couch computer **18** for controlling position of the couch top **10**, and the like. Under the control of a couch mounted computer **18**, the drive motor **12** selectively advances the patient supporting surface into the bore until an isocenter of the localized coil is at an isocenter of the magnet unit **C**.

[0019] A cable **44**, preferably a fiber optic cable, provides data communication between the couch computer **18** and an interface board **46** disposed within the magnet room and an operator control station **D** located outside the magnet room in an operator control facility including a front end interface, control and reconstruction computer assembly **48**. An operator interface and control station **50** includes a human-readable display such as a CRT or flat screen monitor **52** and operator input means including a keyboard **54** and a mouse **56**.

[0020] With particular reference to FIGURE 2, the interface, control, and reconstruction computer assembly **48** includes a magnetic resonance sequence controller **60** for controlling magnetic resonance sequences that are applied to the gradient and radio frequency coils. A digital transmitter **62** transmits radio frequency signals under the control of the sequence controller to the radio frequency coils. A plurality of digital receivers 64_1, 64_2, ..., 64_n demodulate the received resonance signals from each of **n** channels and conveys them to a reconstruction processor **66** which reconstructs the magnetic resonance signals into an image representation which is stored in an image memory **68**. A video processor **70** selectively extracts portions of the stored reconstructed image representation and formats the data for display on the video monitor **52**. The sequence controller **60** also controls gradient amplifiers **72** which control current to the gradient coils **32** (Fig. 1) to create the gradient field profiles of the selected magnetic resonance sequence. A sequence memory **74** stores detailed instructions for performing each of the numerous magnetic resonance sequences which the system is programmed to perform. A sequence loading means **76** is controlled by the keyboard or mouse and an operator control computer **78** to load the detailed instructions for a selected sequence into the sequence controller **60** to be performed.

[0021] The cable **44** conveys the operator instructions and sequence instructions to the couch computer **18** and the interface board **46**. The interface board **46** includes a sequence information interface **80** which conveys the RF coil bias switching pulses to a flexible cable **82** which extends through the patient couch assembly to the socket **26**. The localized coil **B** has appropriate internal connections to connect its associated plug with its radio frequency coils. The plug and socket also connect a coil identification and attribute interrogation unit **84** with an electronic coil attribute storage component **86**. Preferably, the storage component **86** is a two lead EEPROM such as is commercially available from Dallas Semiconductor under the trade name 1-WIRE™.

[0022] The coil interrogation unit **84** in the preferred embodiment periodically polls address space allotted to the EEPROM **86**. When a coil is found, as determined by the presence of data populating the address queried by the interrogation unit **84**, the attribute information

stored on the EEPROM **86** (more fully discussed below) is retrieved and displayed, through display interface **90**, to the operator display panel **40**.

[0023] The coil interrogator **84** also conveys the coil attribute information on the cable **44** to an acceptable mode storage table **96**. Optionally, the acceptable mode storage table **96** may be eliminated with mode data accessed when needed directly from the memory device **86**. The acceptable mode storage table **96** interacts with the sequence loading means **76** such that only sequences which are supported by the identified coil are loaded into the sequence controller **60**. The acceptable mode table **96** acts as an interlock to lock out all but a selected list of modes, which may be accessed by the loading means **76** to determine which sequences are acceptable to be loaded, or the like.

[0024] The localized radio frequency coil **B** may be any type of receive, transmit, or transmit and receive coil of any geometry or configuration. It may contain multiple RF coils which operate in a simultaneously or switched array topology. The RF cable **82**, may be a single coaxial cable of any diameter, multiple cables or fiber optic cables as may be appropriate to the insertable coil.

[0025] The operating modes can be set either by the couch computer **18** or the system computer **78** via the bus **44**. The bus is preferably a serial data and clock bus which daisy chains through several parts of the MR system. Preferably the bus is a multi-master bus with a defined protocol to permit different masters to have control of the bus. The couch and system computers can each act as masters and all of the devices act as slaves to the bus.

[0026] After a valid coil is detected and identified, the interface operating mode is selected by writing the selected mode into the mode register **98** on the interface **46**. The mode is read back from the register **98** to the system computer **78** to verify that the proper test procedures have been selected. The coil is tested by turning the test bit on and off in the register. The test mode validates the channels of the coil which are plugged into the couch as well as the whole body coil and the radio frequency signal transmit/receive switch in the sequence information interface **80**. The results of the coil test are also stored in the mode register **98** to be read by the system computer. If an invalid status or error is determined by the test unit, the display interface **90** displays the appropriate error message on the couch display **40**.

[0027] The front end interface **48** provides the primary link to the bus **44**. The front end interface provides communication to the couch computer to turn it off during a scan, to command horizontal and vertical motion of the couch, and to determine the current position of the couch. The couch position is used to set up array coils, and the like. Communication with the couch mounted interface **46** determines which coil is installed on the couch and causes the testing to be performed on the coil.

[0028] Some functions are preferably duplicated between the couch computer **18** and the front end interface **48**, for example, detection of the coil attribute storage data. The main system computer initiates several tasks through the front end interface prior to initiation of a scan. For example, the scan computer accesses the EEPROM **86** directly over the bus **44** and notifies the operator of the coil or lack thereof. After a valid coil is detected, the primary system computer selects and tests the interface operating mode by writing the mode associated with that coil into the mode register **98**. The mode is read back from the mode register to verify that the test mode has been properly set. The coil is tested as before by turning the test bit on and off in the register **98**. The test mode validates all channels of the coil which are plugged into the couch, as well as the body coil and the power transmit/receive switch in the sequence information interface **80**. The results of the coil test are read into the system computer. If there is an error or invalid coil status, the appropriate error message is displayed. The default operating mode is selected by writing the mode associated with the coil into the mode register **98** and reading back the mode from register **98** to verify that the operating mode has been properly selected.

[0029] The interface board **46** is interlocked with an RF enable signal to a power signal in the sequence interface **80**. During the transmit period, the interface board **46** checks to make sure that the bias current is flowing at the correct levels in the body coil, the high power radio frequency transmit/receive switch, and any coils plugged into the couch connector **26**. During the receive enable period, the body coil and the high power transmit/receive switch are checked in a similar manner. The diagnostic interface provides the primary link to the bus **44** during system power-up/down sequences and during the system diagnostics. The diagnostic interface further provides communication to the couch computer **18** to initiate diagnostic functions. Communication with the interface **46** determines which coil is installed on the couch and performs tests of the coil during diagnostic functions. Communication with the radio frequency amplifier determines whether it is operating properly and performs any functional diagnostic tests of its internal sub-systems. Communications with the system computer initiate diagnostic functions. Communications with the gradient amplifier also initiate diagnostic functions.

[0030] With reference to Figure 3 the electronic coil attribute storage component **86** is preferably an EEPROM of the type commercially available from, for example, Dallas Semiconductor under the trade name 1-WIRE™. The EEPROM **86** is organized such that a first field **100** of 16 bytes is allotted for the coil name. A second field **102** is organized to contain receive and transmit voltage data in addition to transmit current information for each of four separate channels. The remaining fields are organized by mode name, e.g. **104**; with associated bias patterns, e.g. **106**; and associated valid receive signal patterns, e.g. **108**. The voltage and

current information and other coil attributes can also be used to customize settings in the sequence control **60** and the sequence interface **80** for the individual coil in place.

[0031] With reference now to Figure 4, the plug **24** is preferably formed from a non-conductive material shaped to receive at least one electrically conductive coaxial connection element **110.** The 1-WIRE™ EEPROM **86** includes a ground pin **112,** and an active pin **114** on which power and data are conveyed to and from the memory device. The 1-WIRE™ EEPROM has a third physical pin which has no electrical function.

[0032] Cross referencing now Figure 4, 5, and 6 pin **112** is in electrical communication with the outer, ground or shield element **116** of connection element **110.** Additionally, the pin **114** is in electrical communication with a central conductor **118** of the connector **110.** A dielectric **120** holds the central connector **118** in place to interconnect with corresponding portions of the socket **26.** The pin **114** is disposed such that it makes electrical contact with a corresponding central electrical contact **122** within the socket **26.** Further reference to Figure 5 illustrates that the plug **24** contains other connection elements **124** suitable to make additional connections between the coil **B** and the socket **26,** hence the processing equipment located on the MR device itself. Those skilled in the art will appreciate that the other connection elements **124** can be used to connect magnetic resonance signals from the coil **B** to the processing equipment, biasing voltages from the MR machine to the coil, optical data and the like.

[0033] Referring in particular to Figure 6, the plug **24** is adapted to be telescopically received by the socket **26.** To improve clarity, only one of the coaxial connections **110** is shown although others are desirable as discussed above. As the plug **24** is urged into the socket **26,** preferably embedded within the patient support **10,** a mating electrical connector **126** is aligned with and telescopically engages the coaxial connector **110.** The outer shield elements firmly frictionally engage to provide a secure ground or shield connection. One of the center elements is frictionally received telescopically in the other to provide a secure center conductor connection.

[0034] When the plug **24** is in place within the socket **26,** those skilled in the art will appreciate that electrical communication is established between the center conductor of cable **82** and the data pin **114** of the 1-WIRE™ EEPROM. Those skilled in the art will appreciate that the plug/socket assembly illustrated ensures both electrical and mechanical engagement by friction between the plug and socket. Moreover, while the plug **24** need only support the number of coaxial connections needed by any particular individual coil, the socket **26** is configured so as to receive the plug having the maximum number of connections.

[0035] The invention has been described with reference to the preferred embodiments. Modifications and alterations will naturally occur to others upon reading and understanding the preceding detailed description. It is intended that the invention be construed as including all such modifications and alterations insofar as they come within the scope of the appended claims, or the equivalents thereof

Claims

1. Magnetic resonance imaging apparatus comprising: a patient couch (10) which selectively positions a patient relative to an examination region; an imaging coil (22) disposed adjacent a region of interest which at least receives magnetic resonance signals emanating from the patient; a processor (48) which controls an imaging event and processes received magnetic resonance signals from the imaging coil into an image representation; a plug and socket assembly (24, 26) having a proximal component and a distal component relative to the imaging coil (22), the plug and socket assembly (24,26) selectively connecting the imaging coil (22) and the processor (48); and a memory device (86) affixed to the proximal component of the plug and socket assembly (24, 26) which stores a plurality of attributes (102, 104, 106, 108) associated with the imaging coil (22).

2. Magnetic resonance imaging apparatus as claimed in claim 1, wherein the proximal component comprises: a substantially non-conductive housing (24) having a plurality of channels (124) defined within; at least one connector disposed within selected ones of the plurality of channels (124); a selected number of data leads, each affixed at one end to one of the connectors, and affixed at an opposite end to the imaging coil (22); and an electrically conductive connector (110) disposed within an additional one of the plurality of channels (124), wherein the additional connector (110) is in electrical communication with the memory device (86).

3. Magnetic resonance imaging apparatus as claimed in claim 2, wherein the distal component comprises: a substantially non-conductive housing (26) adapted to engage with the housing (24) of the proximal component; mating connectors (126) disposed within channels in the housing, the connectors (126) adapted to cooperate with the connectors (110) of the proximal component providing a selective data path between the proximal component and the distal component; and an electrical lead (122) in electrical communication with a data pin (118) on the memory device (86) when the proximal and distal components are engaged.

4. Magnetic resonance imaging apparatus as claimed

in any one of claims 1 to 3, wherein the memory device (86) comprises a programmable read only memory internally configured to store a coil name (100).

5. Magnetic resonance imaging apparatus as claimed in claim 4, wherein the programmable read only memory comprises exactly one data and power pin (114) and a ground pin (112).

6. Magnetic resonance imaging apparatus as claimed in any one of claims 1 to 5, wherein the data attributes associated with the imaging coil comprise coil bias patterns (106) for selected modes of coil operation (104).

7. Magnetic resonance imaging coil for selective operable connection to a magnetic resonance scanner, the imaging coil comprising: a radio frequency antenna (22) for at least receiving RF signals; a memory device (86) for storing a plurality of attributes (100, 102, 104, 106, 108) associated with the radio frequency antenna (22); a coil-side mating element (24) having a plurality of connectors in signal communication with the radio frequency windings and a coaxial connector (110) connected with the memory device (86), the coil-side mating element (24) being adapted for selective mechanical and data association with a corresponding mating element (26).

8. Magnetic resonance imaging coil as claimed in claim 7, wherein the memory device (86) comprises of an EEPROM disposed within the coil-side mating element.

9. Magnetic resonance imaging coil as claimed in claim 7 or claim 8, wherein the stored attributes comprise a coil name (100) and representative currents and voltages (102) for channels associated with the magnetic resonance imaging coil.

10. Magnetic resonance imaging coil as claimed in any one of claims 7 to 9, wherein the stored attributes comprise representative modes (104), associated bias patterns (106) and valid receive signal patterns (108) associated with the magnetic resonance imaging coil.

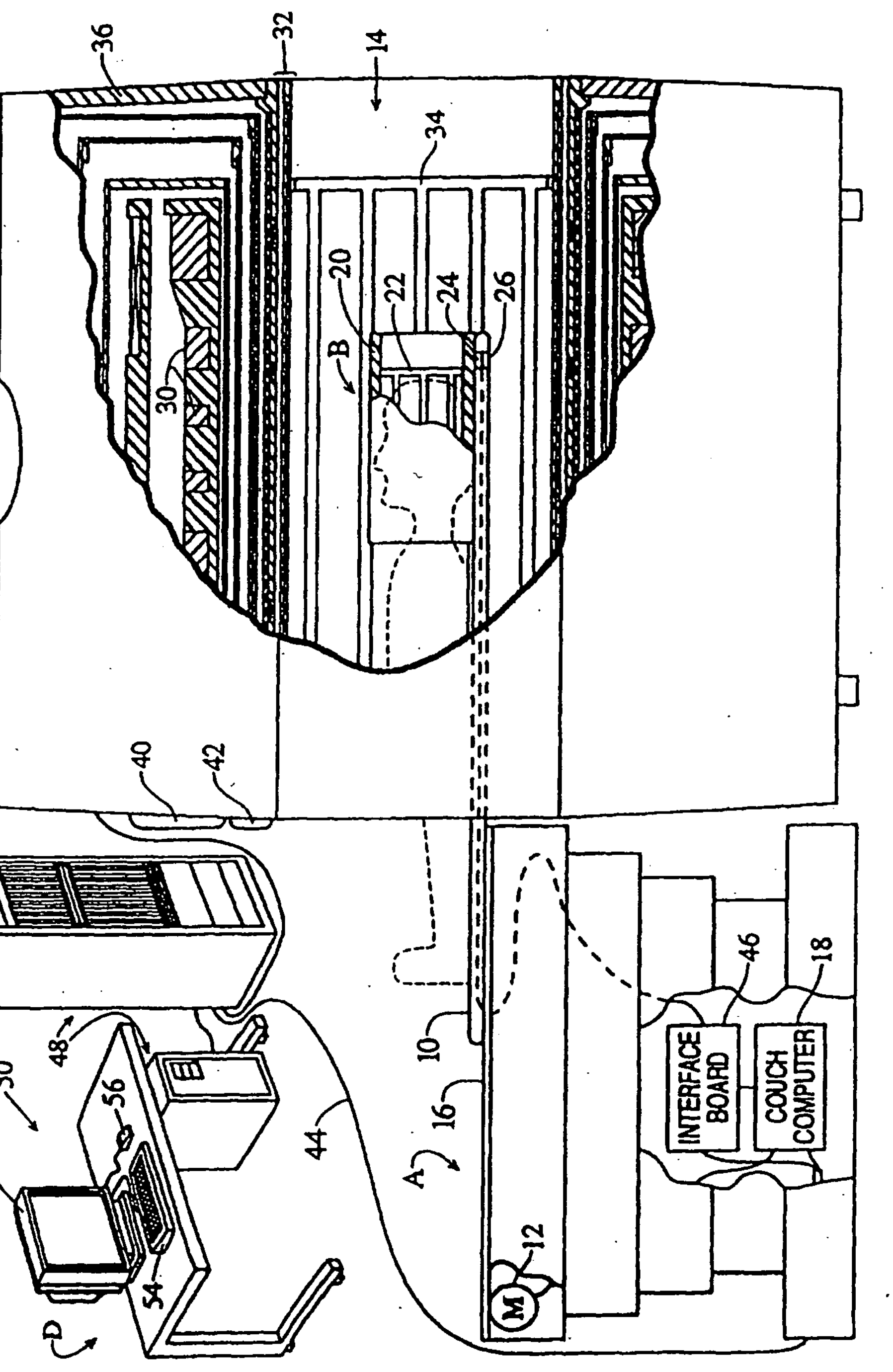


Fig.1

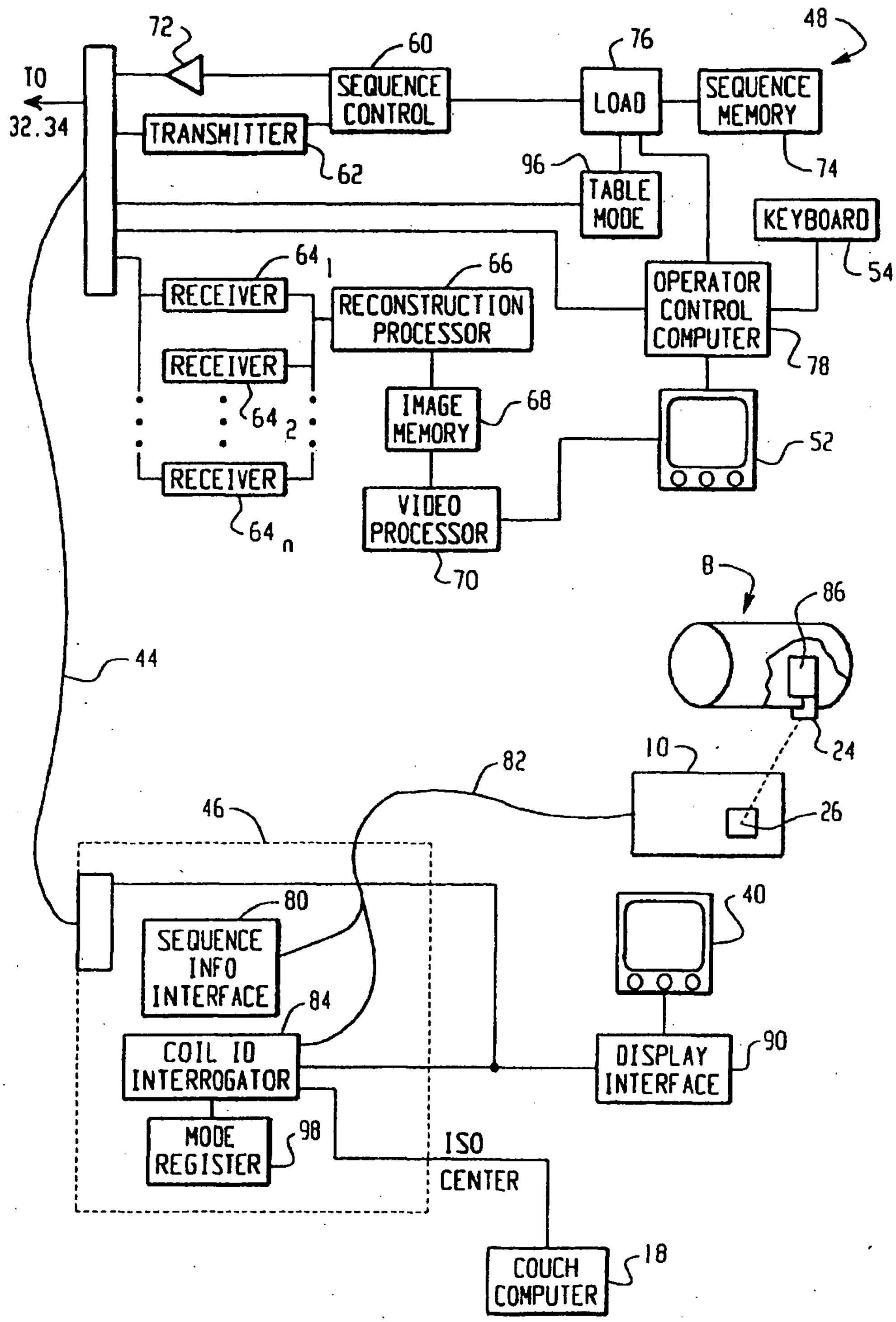
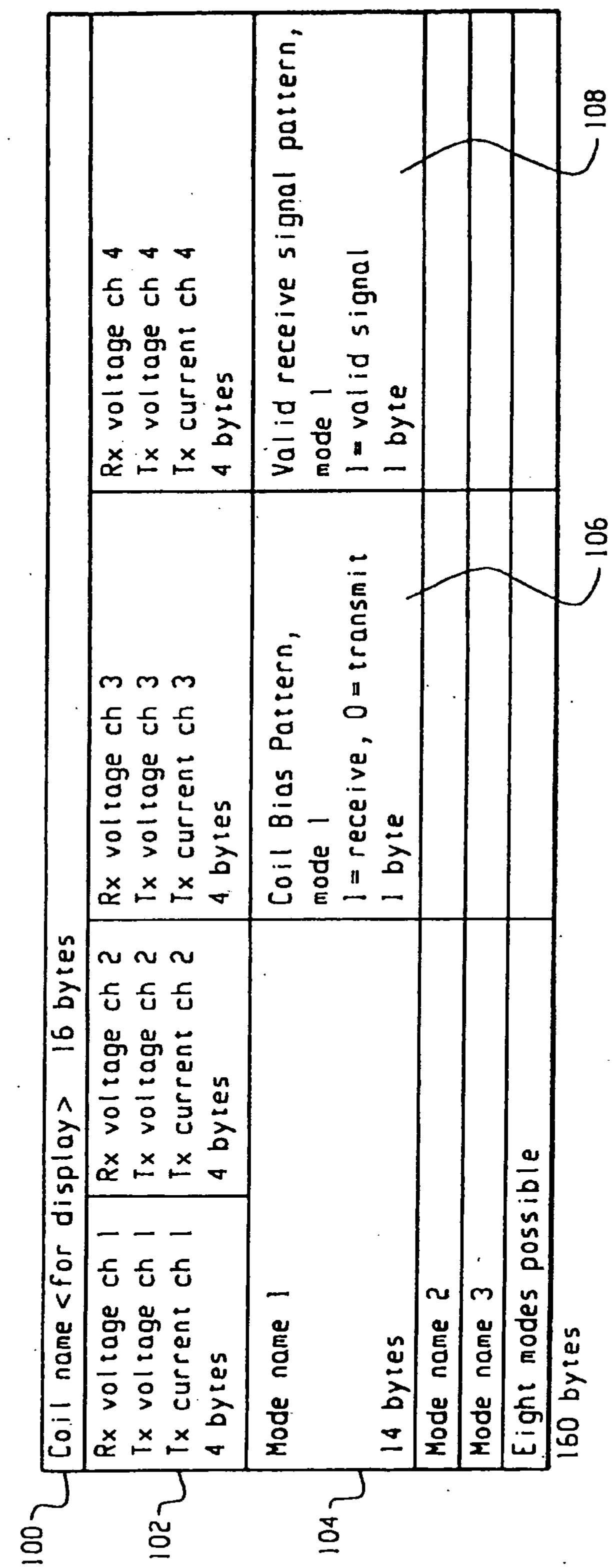

72
60
76
48
TO
32.34
SEQUENCE CONTROL
LOAD
SEQUENCE MEMORY
TRANSMITTER
62
96
TABLE MODE
74
KEYBOARD
54
64 1
66
RECEIVER
RECONSTRUCTION PROCESSOR
OPERATOR CONTROL COMPUTER
78
RECEIVER
IMAGE MEMORY
68
64 2
52
RECEIVER
VIDEO PROCESSOR
64 n
70
8
86
44
24
82
10
46
26
80
40
SEQUENCE INFO INTERFACE
84
COIL ID INTERROGATOR
DISPLAY INTERFACE
90
MODE REGISTER
98
ISO CENTER
COUCH COMPUTER
18

Fig. 2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Rx voltage ch 1
Tx voltage ch 1
Tx current ch 1
4 bytes
Rx voltage ch 2
Tx voltage ch 2
Tx current ch 2
4 bytes
Rx voltage ch 3
Tx voltage ch 3
Tx current ch 3
4 bytes
Rx voltage ch 4
Tx voltage ch 4
Tx current ch 4
4 bytes
Mode name 1
14 bytes
Coil Bias Pattern,
mode 1
1 = receive, 0 = transmit
1 byte
Valid receive signal pattern,
mode 1
1 = valid signal
1 byte
Mode name 2
Mode name 3
Eight modes possible
160 bytes
100
102
104
106
108

Fig. 3

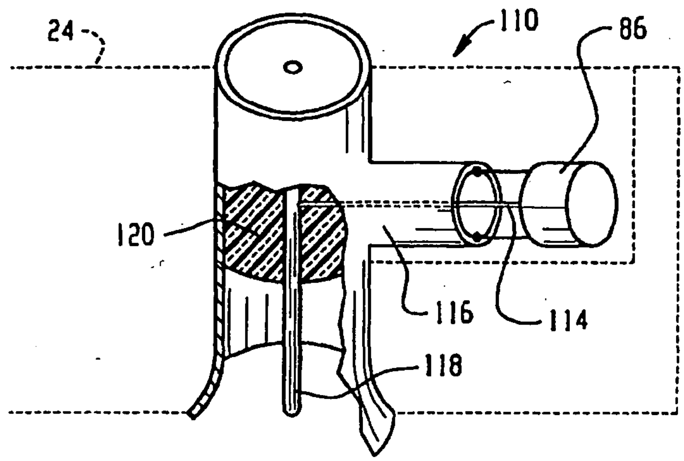
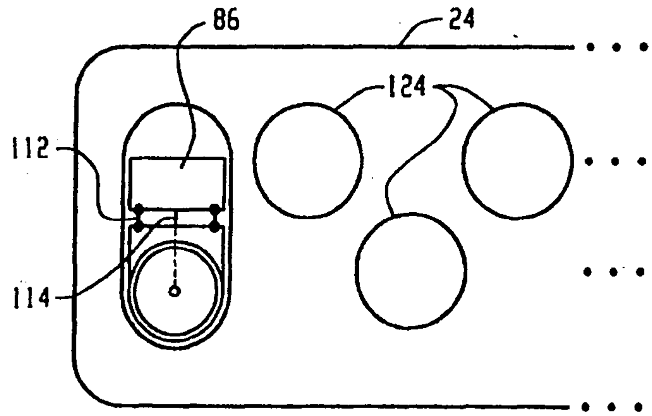


Fig. 4

Fig. 5



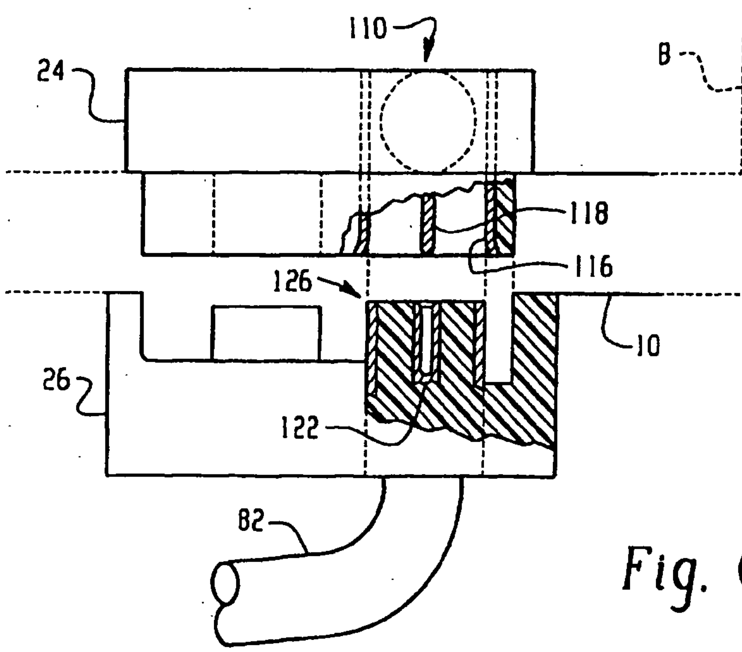


Fig. 6